An Inventory of Stream Habitat, Fish Populations, and Macroinvertebrate Communities with Regards to Removal of a Fish Hatchery Dam on Scotsman Creek, Highlands Ranger District , Nantahala National Forest, North Carolina

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Introduction

Scotsman Creek is a second order tributary of the Chattooga River in the Savannah River drainage (Figure 1). The U. S. Forest Service recently purchased land in the Scotsman Creek watershed, including land once used to support a fish hatchery. While in operation, the hatchery's raceways were supplied with water impounded behind a small (0.8 m in height, 16 m wide) reinforced concrete dam (Figure 2). The water supply mechanism was not functional at the time the land was purchased however the dam was intact.

In July 2000, biologists from the Highlands Ranger District, Nantahala National Forest, North Carolina, contacted the Center for Aquatic Technology Transfer (CATT) to request a preliminary consultation on the potential effects of removing the dam. The Highlands Ranger District was considering the creation of a recreation area near the hatchery site and felt that removal of the dam would decrease potential safety hazards and increase aesthetic quality of the site. District biologists had several concerns, including the following:

1) Would removal of the dam allow non-native rainbow (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) to invade areas upstream of the dam predominantly occupied by native brook trout (*Salvelinus fontinalis*)?

2) Would removal of the dam result in a release of the sediment that had accumulated behind the dam and would this release have detrimental effects downstream?

3) Would removal of the dam and subsequent loss of the large pool above the dam result in a loss of quality brook trout habitat?

4) Would removal of the dam result in a loss of habitat for federally endangered Odonate (dragonfly/damselfly) species known to occupy other areas of the Chattooga River drainage?

A biologist from the CATT visited the site and concluded that fish and habitat surveys and macroinvertebrate samples would provide the information needed to address the concerns of the Highlands Ranger District biologists.

From October 31 to November 2, 2000 a CATT field crew performed fish and habitat surveys and collected macroinvertebrate samples on a 2.5 km reach of Scotsman Creek, including 1.5 km downstream and 1.0 km upstream of the hatchery dam. This report provides the results of the surveys and a discussion of potential effects of removing the hatchery dam.

Methods

Habitat

Standard basinwide visual estimation technique (BVET) habitat survey methods (Hankin and Reeves 1988, Dolloff et al. 1993) were used to measure stream habitat parameters beginning at forest road 1178 and ending 2.5 km upstream (Figure 1). The hatchery dam was located 1.5 km upstream of forest road 1178. Habitat in Scotsman Creek was stratified into similar groups based on naturally occurring habitat units including pools (areas in the stream with relatively low water velocity, streambed gradient near zero, relatively deep water, and a smooth water surface), and riffles (areas in the stream with relatively high water velocity, relatively steep gradient, shallow water, and a turbulent surface). Glides (areas in the stream with moderate water velocity, relatively deep water, and slightly turbulent water surface) were identified during the survey but were grouped with pools for data analysis. Bedrock cascades (areas in the stream with swift current, steep gradient, and exposed rocks and boulders) were grouped with riffles for data analysis.

Two-stage visual estimation techniques were used to quantify habitat in Scotsman Creek. Habitat was classified and inventoried by a two-person crew. One crew member identified each habitat unit by type, estimated maximum and average depths of each habitat unit, measured depth at riffle crest for each riffle, estimated wetted stream width, classified the dominant and subdominant substrata particle size (modified Wentworth scale), and measured the length of each habitat unit to the nearest 0.1 m with a hip chain. The second crew member classified and inventoried large woody debris (LWD) within the active stream channel and recorded data on a Husky Hunter field computer.

Average depth of each habitat unit was estimated by taking depth measurements with a wading rod marked in 5 cm increments at several locations across the stream channel. The widths of 10% of the pools and riffles were measured with a meter tape to calibrate visual estimates of wetted stream width. LWD >1 m in length and >10 cm in diameter was divided into four classes: 1) <5 m long, <55 cm in diameter, 2) <5 m long, >55 cm in diameter, 3) >5 m long, <55 cm in diameter, and 4) >5 m long, >55 cm in diameter.

Total pool area, total riffle area, and total area of the 2.5 km reach were calculated using an Excel spreadsheet (Dolloff et al. 1993). Maximum, average, and riffle crest depths, dominant and subdominant substrates, and LWD data were summarized using Excel spreadsheets and Sigma Plot graphing software.

We also assessed accumulated sediment depth in three areas of the pool behind the hatchery dam (Figure 3). Each area consisted of five transects that were perpendicular to flow and spaced two meters apart. Sediment depth was measured at 0.5 m increments across each transect by driving a wooden stake through accumulated sediment until an impenetrable substrate material was encountered. The data were used to construct 3-dimensional graphs showing the depth of sediment that had accumulated immediately behind the hatchery dam, near the midpoint of the hatchery dam pool, and near the upstream end of the hatchery dam pool. Rebar stakes were driven into the stream banks and orange flags were placed to mark transect locations and to facilitate finding the transects in the future. The stakes were placed in the left bank (as facing upstream) for the two transect areas furthest downstream and were inserted in the right bank at the furthest upstream site.

Fish

A fish survey was performed by electrofishing every fifth (20%) pool and riffle from forest road 1178 to a point 2.5 km upstream. Three passes were made through each habitat unit with a 700V AC backpack electrofishing unit and two netters. Block nets were placed at the upstream and downstream end of each habitat unit before shocking began. In addition we shocked two 50 m long reaches of the hatchery dam pool (Figure 3). The first reach started at the dam and ended at a block net 50 m upstream of the dam. The second reach started at a block net placed 126 m upstream from the dam and ended at a beaver dam 50 m upstream (the upstream end of the hatchery dam pool). The total number of each species captured in each pass was recorded.

Brook trout adult and young-of-the-year (YOY) and blacknose dace (*Rhinichthys atratulus*) population abundances were estimated for each pool and riffle using the three pass depletion calculations described in Kwak (1991). The population abundance of brook trout adult and YOY and blacknose dace was estimated for the entire 2.5 km reach by modifying BVET calculations outlined in Dolloff et al. (1993). We modified BVET protocol by allowing the variance in the multiple-pass removal estimates to represent the total variance in the 95% confidence interval calculation since no diver counts were used in our fish survey. The population density of adult and YOY brook trout and blacknose dace in the entire 2.5 km reach was calculated by dividing the estimated population abundances (as calculated above) by the total reach area (as calculated in the above 'Habitat' section). These estimates included the 50 m reaches from the hatchery dam pool.

Density reported for rainbow trout, brown trout, brown bullhead (*Ameiurus nebulosus*), and striped jumprock (*Scartomyzon rupiscartes*) reflect the total number captured during electrofishing. Capture of these fish species was too low to allow for abundance or density calculations as described above.

Macroinvertebrates

Macroinvertebrates were sampled at six sites throughout the 2.5 km study reach, including three downstream and three upstream of the hatchery dam (Figure 2). Within each site a representative pool and riffle were chosen. A 1.0 m long, 10 cm deep sample was taken from the pool benthos at each site with a D-frame net. This sample was then placed into the site sample bottle. Next, a single kick-seine (500 micron mesh) sample was taken from a representative riffle. We field picked the kick seine sample because we were unable to wash the entire sample off of the kick seine and into the sample bottle. The kick seine sample was field picked (picking as many specimens as possible on site) for 20 person-minutes (one person picking for 20 minutes per sample or two people picking for 10 minutes each per sample). These specimens were placed in the same sample bottle as the D-frame sample. Sample sites were numbered consecutively starting downstream and continuing to the farthest upstream site. All samples were comprised of one pool and one riffle sample except for site four which was taken directly above the hatchery dam. At this site only a pool sample was taken because there was no riffle habitat for 513 m above the hatchery dam. The site samples were brought back to the lab where they were picked, sorted, and identified to Family level (Merritt and Cummins 1996). Fourteen metrics and the Bray-Curtis Similarity Coefficient were calculated to compare each of the site samples using an Excel spreadsheet. The 14 metrics were as follows:

- Taxa - total number of taxa found for each sample
- Total N - total number of specimens found in each sample
- % 5 Dominant Taxa - abundance of specimens in the five most prevalent taxa compared to total number of specimens per sample
- Modified HBI - modified version of the Hilsenhoff Biotic Index (tolerance values range from 0–10; with 0 being the best biotic integrity)
- % Haptobenthos - percentage of specimens in the sample that lay on or attach to the substrate (need clean, course substrate)
- EPT Index - total number of taxa in the orders of Ephemeroptera, Plecoptera, and Tricoptera
- % EPT - total number of specimens in the orders of Ephemeroptera, Plecoptera, and Tricoptera divided by total number of specimens multiplied by 100
- # Ephemeroptera - total number of taxa in the order of Ephemeroptera
- % Ephemeroptera - total number of specimens in the order Ephemeroptera divided by total number of specimens multiplied by 100
- # Plecoptera - total number of taxa in the order of Plecoptera
- % Plecoptera - total number of specimens in the order Plecoptera divided by total number of specimens multiplied by 100
- SDI - Simpson Diversity Index (Index of site diversity; scale of 0-1 with 1 being the best)
- # Intolerant Taxa - total number of taxa from each sample that had a tolerance value of 0-5 on a 0-10 scale
- % Scrapers - total number of specimens that are in the scraper functional feeding group divided by the total number of specimens multiplied by 100

Results

Habitat

Entire Study Reach

We identified 84 pools and 57 riffles in the 2.5 km reach of Scotsman Creek. Visual estimates of habitat area were paired with measured habitat area for 10 (12%) pools and 7 (12%) riffles. We estimated that the reach contained 76% pool habitat (8721±536 m^2) and 24% riffle habitat (2762±371 m^2) (Figure 4). Total area was estimated for pools and riffles using correction factors of 1.16 and 1.12, respectively.

Maximum pool depths ranged from 10 cm to 140 cm, with a mean of 44 cm and maximum riffle depths ranged from 5 cm to 100 cm, with a mean of 17 cm (Figure 5). Average pool depths ranged from 8 cm to 85 cm, with a mean of 24 cm and average riffle depths ranged from 2 cm to 20 cm, with a mean of 7 cm.

Sand was the most common dominant substrate in pools, bedrock was the most common dominant substrate in riffles, and organic matter was the most common subdominant substrate in both habitat types (Figure 6). Together, sand or bedrock were the dominant substrate in 52% of the pools in the study reach.

The study reach contained 190 pieces of LWD per km, of which the majority was <5 m long, < 55 cm in diameter (Figure 7). There were 16 pieces per km of LWD >5 m in length, > 55 cm in diameter in the study reach. Pieces >5 m in length and >55 cm in diameter are the most persistent and most likely to form habitat units in the stream channel.

Accumulated sediment depth in the hatchery dam pool increased from the bottom (furthest downstream) to the top (furthest upstream) of the pool (Figure 9). Maximum accumulated sediment depth immediately behind the dam was 30 cm – 40 cm. The right side of the channel had no accumulated sediment and had a bedrock substrate. Maximum accumulated sediment depth near the midpoint of the pool was 50 cm – 60 cm. Substrate beneath this section appeared to be small gravel to pebble sized. Maximum accumulated sediment depth near the top of the pool was 80 cm to 90 cm. Substrate beneath this section also appeared to be small gravel to pebble sized.

Study Reach Sections

Dominant substrate and distribution of LWD changed noticeably as we moved upstream in the study reach. We divided the reach into five sections based on changes in channel morphology and riparian land use to help us interpret the LWD distribution and substrate data. The five sections were as follows:

- Section 1 extended from forest road 1178 to an 8 m high waterfall/cascade 707 m upstream from forest road 1178. Section 1 was relatively low gradient and had relatively small surface area, shallow pools and riffles. The riparian area was forested, however there were often openings in the tree canopy over the stream channel.

- Section 2 extended from the waterfall/cascade to the base of the hatchery dam (1442 m upstream of forest road 1178). Section 2 also had a forested riparian area but was high gradient with long bedrock cascades broken only by an occasional pool. As a result there were fewer habitat units in section 2 than in section 1 (Table 1).

- Section 3 extended from the hatchery dam to the end of the second beaver pond (1955 m upstream of forest road 1178). Section 3 was low gradient and consisted of only three long pools, one created by the hatchery dam and two more created by beaver dams. The furthest upstream pool in this section crosses onto privately owned land.

- Section 4 extended from the end of the beaver dam ponds to the state highway 1101 bridge (2143 m upstream from forest road 1178). Section 4 was low gradient with relatively short, small surface area pools and riffles. This section was entirely on privately owned land and its riparian area consisted mostly of fallow fields with few trees.

- Section 5 extended from the state road 1101 bridge to the end of the study reach (2500 m upstream of forest road 1178). This low gradient section had relatively short, small surface area pools and riffles. The entire section was privately owned. Its riparian area was forested and a dense rhododendron canopy covered the channel.

As we progressed upstream from forest road 1178 the most common dominant substrate in pools shifted from sand and bedrock to large gravel (Table 1). The percentage of pools with sand or bedrock as the dominant substrate was lowest in the section furthest upstream (section 5). The percentage of pools with small or large gravel as the dominant substrate was highest in the two sections upstream of the hatchery and beaver dam pools.

LWD was distributed throughout section 1 (Figure 8). Section 2 consisted mostly of long bedrock cascades, resulting in a lower number of habitat units per kilometer than in section 1 (Table 1). Because there were fewer habitat units but each occupied a relatively large area of the stream the amount of LWD in a given unit was exaggerated in Figure 8. The same could be said for section 3, where there were a total of only three habitat units within the more than 500 m reach of stream. In this extreme case the amount of LWD per unit was greatly exaggerated. Much of the LWD in section 3 was located in the beaver dams that formed two of the three pools. Section 4 had the lowest counts of LWD and no LWD >5 m long, >55 cm in diameter. LWD was distributed throughout section 5.

Fish

Entire Study Reach

Six species of fish were captured in the study reach of Scotsman Creek. Population density of adult brook trout was less than two fish per 100 m^2 and density of YOY brook trout was less than four fish per 100 m^2 (Table 2). Blacknose dace population density was less than five fish per 100 m^2 for the 2.5 km reach. Low capture rate precluded population density calculation for rainbow trout, brown trout, striped jumprock, and brown bullheads.

Study Reach Sections

We divided the stream into the same five sections described in the above 'Habitat' section to further interpret the population density data and to investigate distributional trends for each species. Note that the population densities reported in Figure 10 were standardized by calculating the number of fish per 100 m^2. In many habitat units low numbers of fish were captured, which could lead to confusion in interpretation of the figure. For example, we reported a population density of approximately ten fish per 100 m^2 for rainbow trout in the only pool in which a rainbow trout was captured. This should not be interpreted to mean that we captured ten rainbow trout, but rather that we captured one rainbow trout in a pool approximately 10 m^2 in size.

We captured adult brook trout in all but the furthest upstream section (Figure 10). A pool in section 4 had the highest density (23 per 100 m^2) of adult brook trout in the entire study reach. We captured YOY brook trout in all five sections. Pools in section 4 had the highest density of YOY brook trout in the entire study reach, averaging 21.3 YOY/100 m^2.

Brown trout and rainbow trout were each found in only one section of the study reach. All brown trout were captured downstream of the waterfall/cascade that marked the upstream boundary of section 1. A single rainbow trout was captured in a small pool between two bedrock cascades in section 2.

Striped jumprock and blacknose dace were only found in section 1, downstream of the waterfall/cascade that marked the end of the section. Brown bullheads were restricted to the large pool behind the hatchery dam in section 3. We did not electrofish in the beaver ponds due to logistic and time constraints.

Macroinvertebrates

Sample 1- A total of 609 organisms of 30 different taxa were found at this site (Table 3, Appendix A). About 93% of the organisms at this site to be haptobenthic. The EPT Index at this site was 18, and 26% of the organisms were Emphemeropterans. Simpson Diversity Index had a score of 0.80, and there were 22 intolerant taxa found at this site that were considered intolerant taxa. The functional feeding group of scrapers made up about 47% of the sample at this site.

Sample 2- A total of 329 organisms of 27 different taxa were found at this site. About 64% of the organisms at this site to be haptobenthic. The EPT Index at this site was 15, and 35% of the organisms were Emphemeropterans. Simpson Diversity Index had a score of 0.92, and there were 20 intolerant taxa found at this site that were considered intolerant taxa. The functional feeding group of scrapers made up about 16% of the sample at this site.

Sample 3- A total of 314 organisms of 23 different taxa were found at this site. About 87% of the organisms at this site to be haptobenthic. The EPT Index at this site was 13, and 49% of the organisms were Emphemeropterans. Simpson Diversity Index had a score of 0.86, and there were 16 intolerant taxa found at this site that were considered intolerant taxa. The functional feeding group of scrapers made up about 38% of the sample at this site.

Sample 4- A total of 125 organisms of 8 different taxa were found at this site. About 2% of the organisms at this site to be haptobenthic. The EPT Index at this site was 2, and less than 1% of the organisms were Emphemeropterans. Simpson Diversity Index had a score of 0.21, and there were 4 intolerant taxa found at this site that were considered intolerant taxa. The functional feeding group of scrapers made up less than 1% of the sample at this site.

Sample 5- A total of 332 organisms of 24 different taxa were found at this site. About 43% of the organisms at this site to be haptobenthic. The EPT Index at this site was 15, and 40% of the organisms were Emphemeropterans. Simpson Diversity Index had a score of 0.81, and there were 17 intolerant taxa found at this site that were considered intolerant taxa. The functional feeding group of scrapers made up about 8% of the sample at this site.

Sample 6- A total of 63 organisms of 16 different taxa were found at this site. About 62% of the organisms at this site to be haptobenthic. The EPT Index at this site was 8, and 17% of the organisms were Emphemeropterans. Simpson Diversity Index had a score of 0.93, and there were 12 intolerant taxa found at this site that were considered intolerant taxa. The functional feeding group of scrapers made up about 21% of the sample at this site.

Bray-Curtis results (Table 4) ranged from zero to one, with one indicating highest and zero indicating lowest similarity (>0.7=similar, <0.5=dissimilar, and 0.5 to 0.7=unknown). Site four was the most dissimilar to the other sites, with all scores below 0.3 (Table 4). None of the comparisons between sites had a score high enough to show similarity.

Discussion

Our discussion focuses on the four major concerns of the Highlands Ranger District biologists regarding removal of the hatchery dam.

1) Would removal of the dam allow non-native rainbow and brown trout to invade areas upstream of the dam predominantly occupied by native brook trout?

The hatchery dam is less than 1.0 m in height and 16 m wide. It was breeched on one side and had water flowing over the other. Generally speaking a much more substantial obstacle would be necessary to obstruct trout movement (Adams et al. 2000). The only potential barrier to fish movement that we encountered was the waterfall/cascade 707 m upstream from forest road 1178, upstream of which no brown trout were captured (Figure 10). A rainbow trout was captured upstream of the waterfall/cascade and a local landowner reported catching rainbow trout upstream of the hatchery dam. If rainbow trout were already occupying areas upstream of the hatchery dam it would nullify the dam's effect as a barrier against invasion. It does not seem likely that the native brook trout population would be further threatened by an invasion of brown or rainbow trout following removal of the hatchery dam.

2) Would removal of the dam result in a release of sediment that had accumulated behind the dam and would this release have detrimental effects downstream?

The hatchery dam pool is over 175 m in length and has accumulated sediment greater than 80 cm deep in areas near the top of the pool (Figure 9). However, near the bottom of the pool accumulated sand deposits are less than 40 cm deep on the left side of the channel and the right side of the channel had no deposits and was underlain by bedrock. This bedrock channel is discernable for at least 30 m behind the dam (Craig Roghair, pers. obs.). Since the accumulated sediment is spread throughout the pool with the thickest deposits furthest upstream it does not seem likely that all the sediment that has accumulated in the pool would be released immediately upon dam removal. Sediment that has accumulated immediately behind the hatchery dam could easily be manually removed to further decrease the amount of sediment released at the time of dam removal.

Sediment that is released during or after removal of the hatchery dam will travel through a 700 m long series of bedrock cascades and pools (section 2) before arriving at a lower gradient reach of stream (section 1). Nearly 60% of the pools in section 1 already have sand as their dominant substrate. It is not likely that this would increase following the release of the relatively small amount of sediment (mostly sand) held in the hatchery dam pool. Flushing flows should remove or disperse any released sediment rather quickly.

Highlands Ranger District biologists also questioned whether bank stabilization techniques should be employed to prevent erosion of exposed banks along the reach of stream formerly occupied by the hatchery dam pool should the hatchery dam be removed. Several stream bank stabilization references describe techniques that range from minimizing activity in the riparian area and allowing the channel to stabilize naturally (Hunter 1991), to using native vegetation to stabilize banks (Shields et al. 1995, Watson et al. 1997), to installing elaborate structures and riprap (Hunt 1993). These methods range greatly in intensity and cost, thus all sources stress the importance of project design and planning before initiating any habitat manipulation project.

3) Would removal of the dam and subsequent loss of the large dam pool result in a loss of quality brook trout habitat?

Before we could determine whether removing the hatchery dam would result in a loss of quality brook trout habitat we needed to determine if the hatchery dam pool was indeed quality brook trout habitat. Several of our results indicated that the hatchery dam pool was not quality brook trout habitat. The macroinvertebrate sample taken from the hatchery dam pool had the lowest diversity of taxa and the lowest EPT index suggesting a high rate of perturbation and low water quality (Table 3). The 5% dominant taxa made up nearly 97% of the total macroinvertebrate sample and was dominated by chironomids (Appendix A). The substrate in the pool consisted almost exclusively of sand covered by a thin layer of silt, providing little potential for brook trout reproduction. Brook trout typically spawn on substrates represented by small to large gravel substrate categories and fine particulate matter greatly decreases redd success (Waters 1995). The hatchery dam pool had neither the highest density of YOY or adult brook trout in the study reach. The highest densities of both were found upstream of the hatchery and beaver dam pools where macroinvertebrate indices and habitat surveys indicated better conditions for brook trout. Removing the hatchery dam would increase habitat diversity by exposing riffles and a variety of buried substrates. This in turn would likely increase macroinvertebrate diversity and increase brook trout spawning habitat.

Removing the dam will likely decrease the amount of brown bullhead habitat in the stream. We observed brown bullheads only in the hatchery dam pool. This species was likely released from the hatchery or from a bait bucket during hatchery operation. Brown bullheads likely occupy the two large pools that were created by beaver dams upstream of the hatchery dam pool.

4) Would removal of the hatchery dam result in a loss of habitat for federally endangered Odonate species known to occupy other areas of the Chattooga River drainage?

The macroinvertebrate samples collected in and immediately below the hatchery dam pool had the lowest specimen counts and diversity of Odonate families (Table 5). Macroinvertebrate collection sites 1 and 2 (both collected from study reach section 1) had fewer Odonate taxa and lower total counts of Odanates than those collected at sites 5 and 6 (collected from study reach sections 4 and 5). All Odonate samples listed in Table 5 are being delivered to Highlands Ranger District biologists for identification to species level. Until identification is completed we cannot determine if federally endangered species occupy either the hatchery dam pool or the study reach on Scotsman Creek.

Recommendations

Contingent on identification of the Odonate samples, we recommend that the hatchery dam on Scotsman Creek be removed. The hatchery dam is not an obstacle to brown or rainbow trout invasion, does not pose a major sedimentation threat, and does not create quality brook trout habitat. The hatchery dam would create a safety and liability problem and would be aesthetically unpleasing if the area were converted to recreational use. There is a possibility that given the high amount of beaver activity in the area, the concrete dam will be replaced by a beaver dam. If this were to happen, at the very least removal would eliminate the safety, liability, and aesthetic problems associated with the present structure.

Removal of the hatchery dam will expose the stream banks that are presently inundated by the dam pool. These banks will initially be unstable, however we recommend a minimalist approach to streambank stabilization. Minimizing activity in the riparian area and allowing the banks and channel to stabilize naturally may be sufficient. The area should be monitored to determine if more intensive streambank stabilization techniques become necessary.

It is our opinion that removing the hatchery dam in early spring would minimize the short-term impacts to the stream and to the brook trout population. High flows during late spring should help to create a channel in the stream reach formerly occupied by the hatchery dam pool and to disperse and flush sediment washed downstream. Removing the dam in early spring minimizes the effect of sediment on brook trout spawning during the fall and on YOY which should emerge later in the spring.

Hatchery dam removal should be followed by a series of short and long-term surveys. Short-term surveys should include macroinvertebrate collections and measurements of accumulated sediment depth. The macroinvertebrate samples and measurements of accumulated sediment depth should follow the protocols used in the present report to facilitate comparison of pre- and post-dam removal results. Macroinvertebrate samples should be collected at approximately the same locations as pre-removal samples (Appendix A). Post-removal sediment depth transects should be at the same location as pre-removal transects, which are marked by permanent rebar stakes (Figure 3). Long-term surveys should include continued monitoring of changes in accumulated sediment depth and streambank stability in the reach formerly occupied by the hatchery dam pool as well as a full post-removal survey encompassing all of the methods outlined in the present report. At least a year should pass before a full post-removal survey is performed.

Consideration should be given to performing the full post-removal survey at the same time of year and at similar discharges as the present survey. Differences in discharge can affect estimates of habitat features (Hildebrand et al. 1999). The present habitat survey was performed during a period of low flow. Measurable rain had not been received in the 30 days prior to the habitat survey. This could affect comparisons to future habitat surveys. Performing the macroinvertebrate and fish samples at the same time of year would provide the most valid data for comparison of pre- and post-removal results.

In conclusion we recommend that Highlands Ranger District biologists contact individuals with experience in small dam removal. John Nelson of the Wisconsin Department of Natural Resources has been involved in performing and studying several small dam removal projects and has expressed interest in consulting on the present project. John can be reached by phone (920) 892-8756 or email nelsoj@dnr.state.wi.us to discuss dam removal, sediment management, or streambank stabilization techniques.

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Table 1. Summary of pool habitat characteristics for each study reach section. Percentages represent the percentage of habitat units within each section that had sand, bedrock, or gravel as the dominant substrate type. Gravel percentage included both large and small gravel types. Stream section 3 was removed from comparison because only three pools were present in the section.

Stream Section	Length (m)	Pools per km	Most Common Substrate	Sand (%)	Bedrock (%)	Gravel (%)
1	728	53	sand	59	5	13
2	714	25	bedrock	11	83	0
3	513	6	--	--	--	--
4	188	42	large gravel	25	0	75
5	316	72	large gravel	9	0	61

Table 2. Population estimates (a) or counts (b) of all species captured by electrofishing in the 2.5 km study reach on Scotsman Creek. BVET fish population density estimates were performed only for species in Table 2a. Too few individuals were captured during electrofishing to allow BVET population estimates to be performed for species listed in Table 2b.

a.	Species	Habitat Type	Fish/100m^2	95% Confidence Interval
	brook trout, adult	pool	1.1	0.1
		riffle	0.2	0.0
	brook trout, YOY	pool	3.5	0.2
		riffle	0.6	0.1
	blacknose dace	pool	4.8	0.3
		riffle	0.4	0.4

b.	Species	Habitat Type	Total # Captured
	brown trout	pool	2
		riffle	2
	rainbow trout	pool	1
		riffle	0
	striped jumprock	pool	5
		riffle	0
	brown bullhead	pool	7
		riffle	0

Table 3: Results of the 14 metrics for each of the six macroinvertebrate site samples.

Metrics	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
TAXA	30	27	23	8	24	16
TOTAL N	609	329	314	125	332	63
% 5 Dominant Taxa	74.2	55.6	76.8	97.6	78.0	57.1
Modified HBI	3.34	3.40	2.93	6.01	4.10	3.10
% Haptobenthos	92.9	63.5	86.6	1.6	42.8	61.9
EPT Index	18	15	13	2	15	8
% EPT	51.1	61.7	71.3	1.6	79.5	58.7
# Ephemeropera	5	4	4	1	5	3
% Ephemeroptera	25.9	35.0	49.4	0.8	40.4	17.5
# Plecoptera	5	4	5	0	4	3
% Plecoptera	5.4	6.7	17.5	0	4.8	19.1
SDI	0.80	0.92	0.86	0.21	0.81	0.93
# Intolerant Taxa	22	20	16	4	17	12
% Scrapers	47.0	15.5	37.6	0.8	7.5	20.6

Table 4: Results for the Bray-Curtis Similarity Coefficient (ranging from zero to one), where one indicates highest similarity and zero indicates least similarity.

SAMPLES	S1	S2	S3	S4	S5	S6
S1	1.000	0.420	0.485	0.030	0.272	0.125
S2		1.000	0.476	0.165	0.430	0.204
S3			1.000	0.023	0.229	0.196
S4				1.000	0.179	0.074
S5					1.000	0.268
S6						1.000

Table 5: Total number of each Odonates collected at each macroinvertebrate sample site.

Site		Family	Specimens
Site 1		CORDULEGASTRIDAE	3
		GOMPHIDAE	2
	Total	2	5
Site 2		CORDULEGASTRIDAE	1
		GOMPHIDAE	2
	Total	2	3
Site 3		AESHNIDAE	1
	Total	1	1
Site 4		GOMPHIDAE	1
	Total	1	1
Site 5		CORDULEGASTRIDAE	4
		GOMPHIDAE	3
		AESHNIDAE	2
	Total	3	9
Site 6		CORDULEGASTRIDAE	9
		GOMPHIDAE	4
		AESHNIDAE	1
	Total	3	14

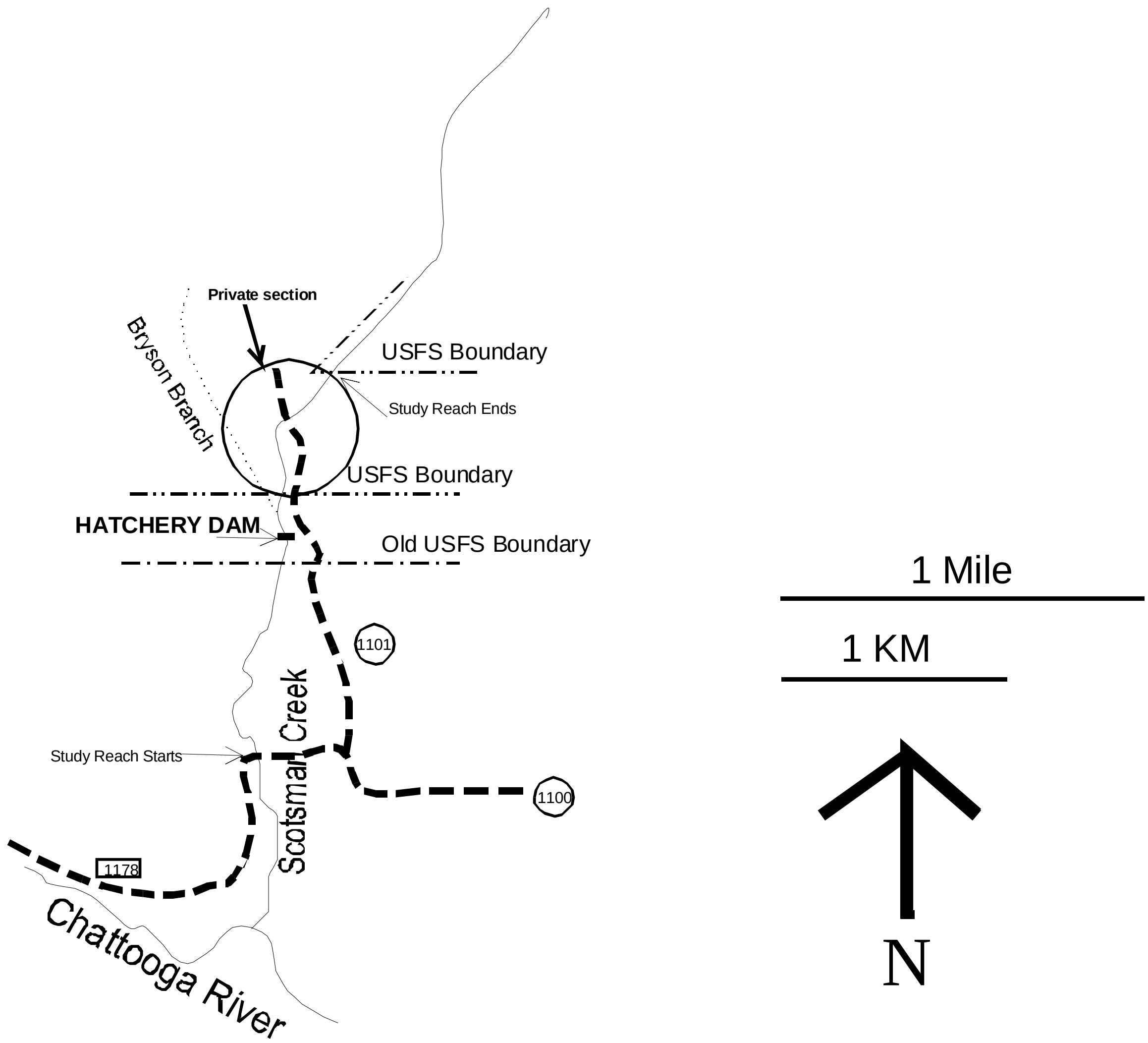

Figure 1. Scotsman Creek area with the starting and ending points of the study reach indicated. The map includes state and forest roads, and the new and old USFS boundaries. The private section of land that was included in the study is also delineated. Bryson Branch and the Chattooga River are shown for orientation.

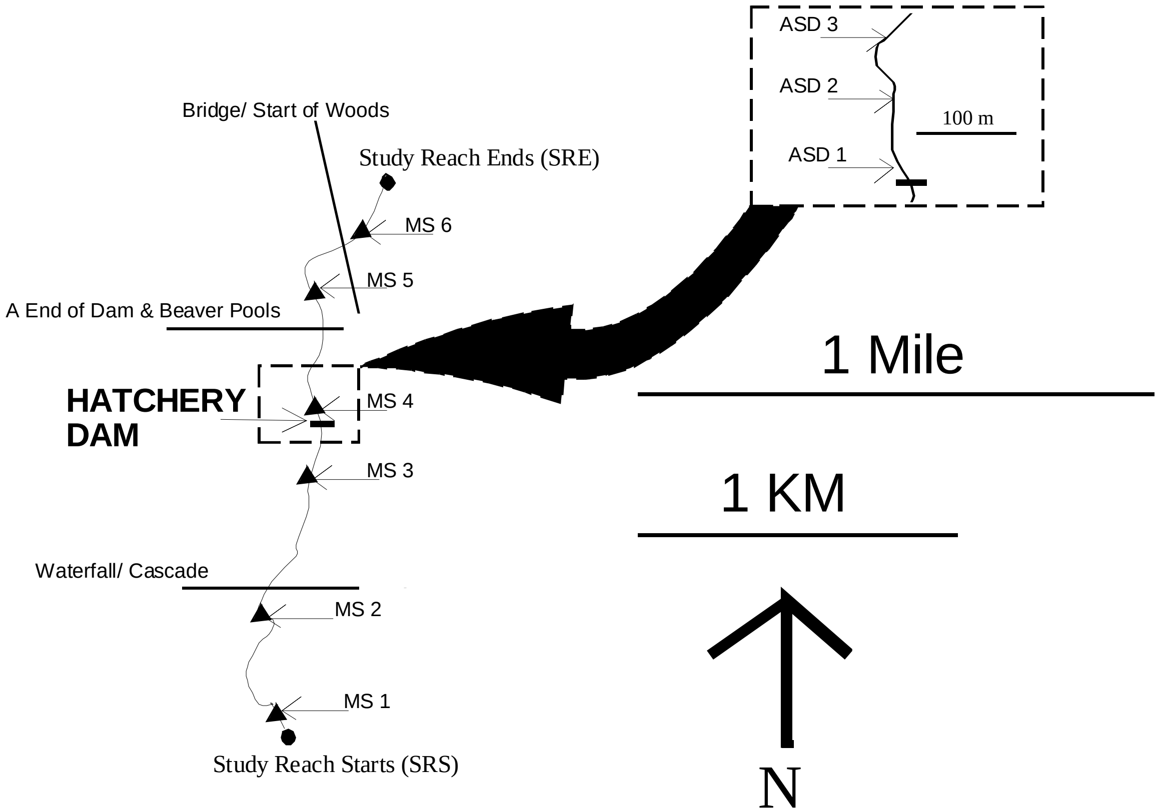

Figure 2. The study reach, study reach sections, and macroinvertebrate sample sites on Scotsman Creek, with an inset showing the hatchery dam pool area. The closed circles represent the starting (SRS) and ending (SRE) points for the study reach. Closed triangles represent the macroinvertebrate sampling (MS) locations. The waterfall, hatchery dam, end of hatchery dam & beaver pools, and bridge represent the break points for the study reach sections. The inset in the upper right hand corner shows the hatchery dam pool area with accumulated sediment depth (ASD) transects locations (Figure 3). See Appendix B for the distances and/or the GPS coordinates for each of these sites.

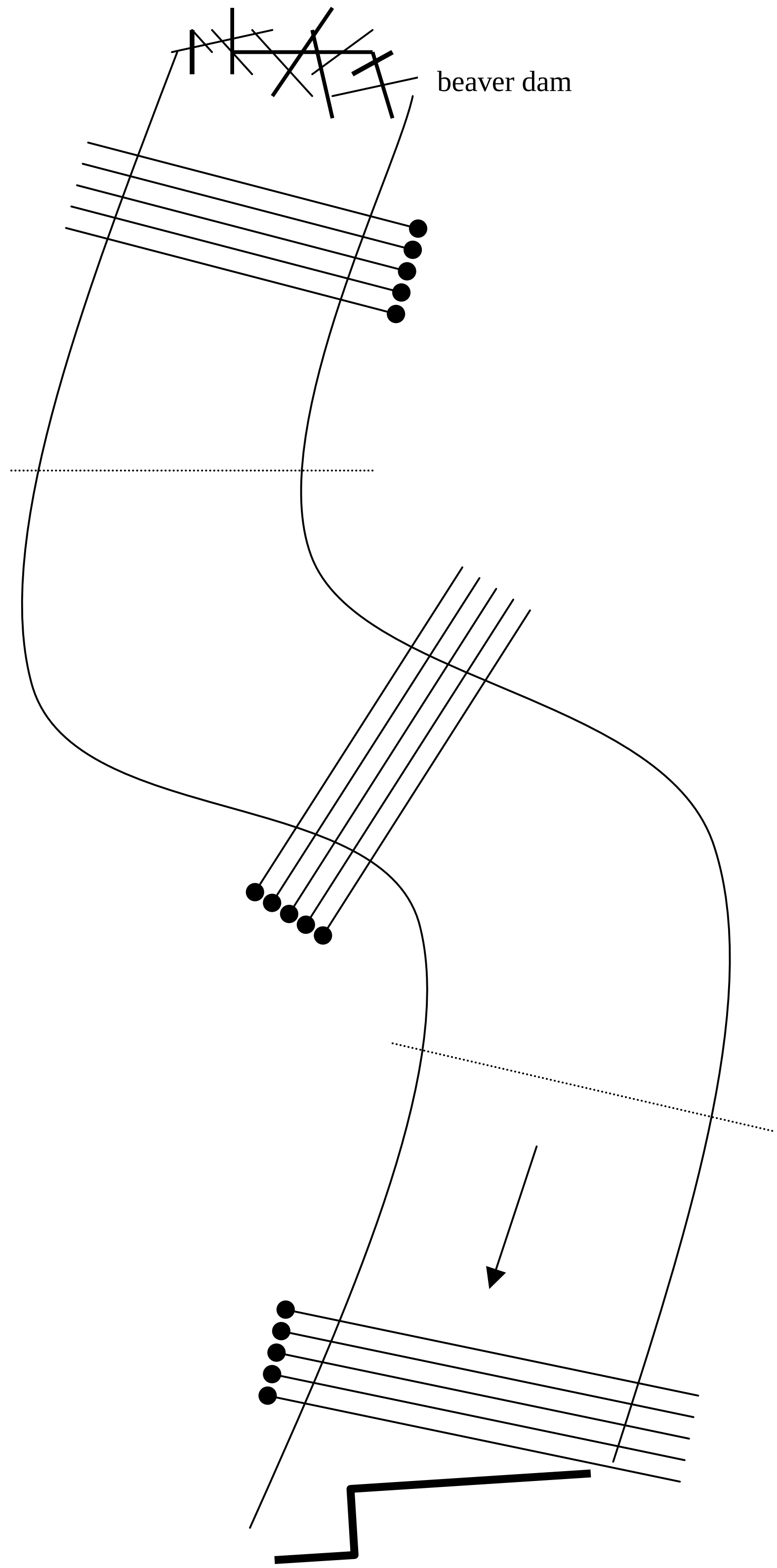

Figure 3. Diagram of the hatchery dam pool on Scotsman Creek. The thick line at the downstream end of the pool represents hatchery dam location. Arrow indicates direction of flow. Solid lines with closed circles represent accumulated sediment depth transect locations. Closed circles represent permanent rebar stakes. Dotted lines represent block net locations during electrofishing. Drawing is not to scale.

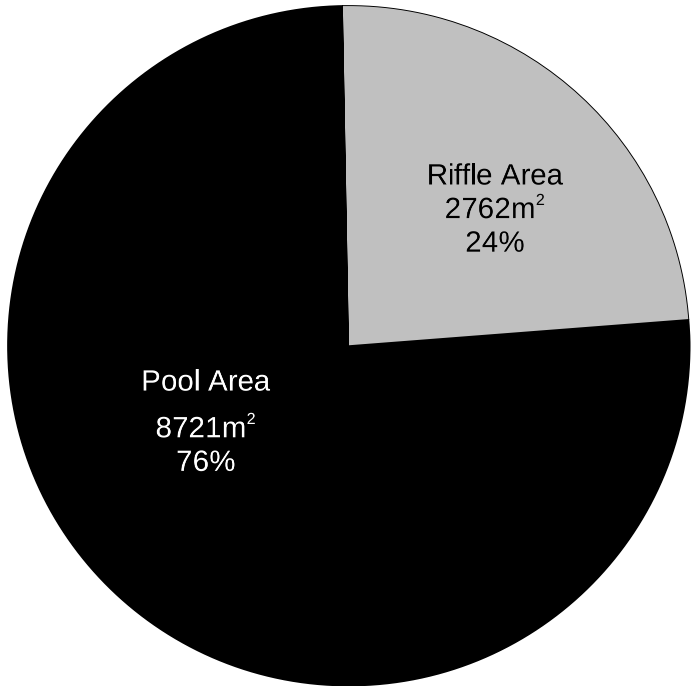

Figure 4. Total and percent pool and riffle surface area in the study reach of Scotsman Creek.

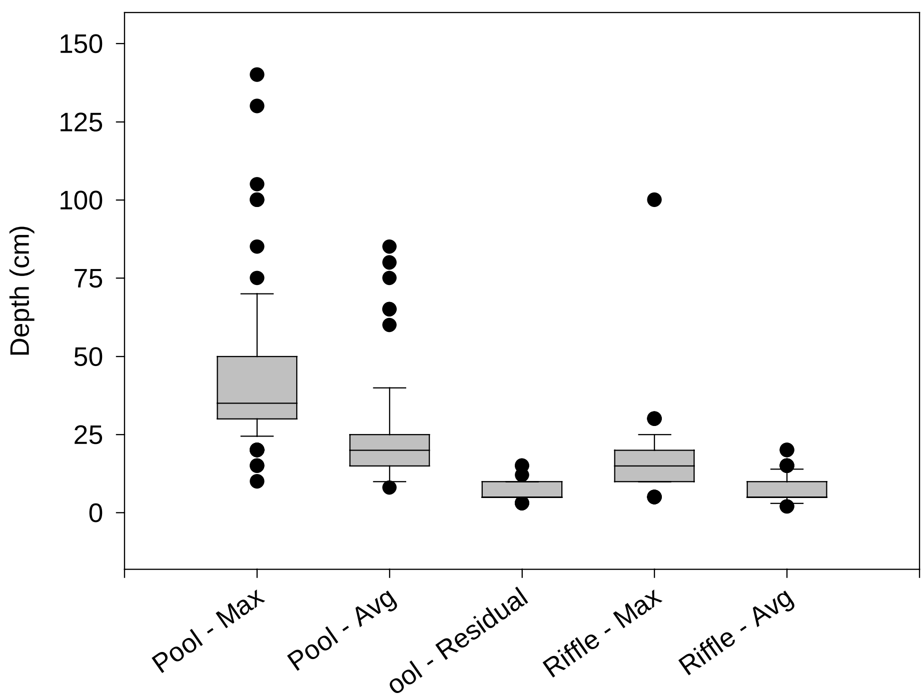

Figure 5. Box plots representing maximum and average depths for pools and riffles, and average residual pool depths in the study reach of Scotsman Creek. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of the box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

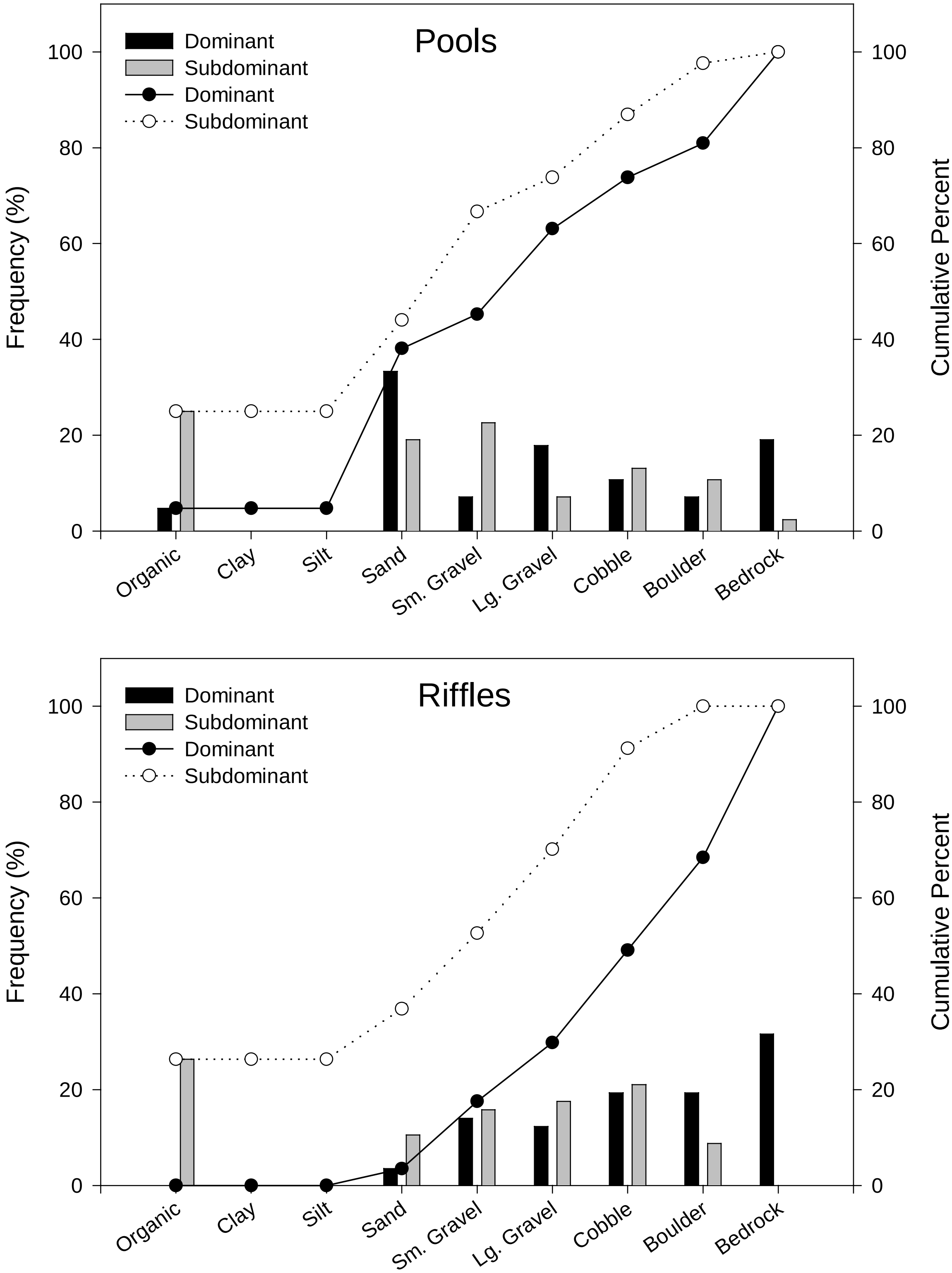

Figure 6. Frequency (percent) and cumulative percent of dominant and subdominant substrate occurrence for pool and riffle habitat in the study reach of Scotsman Creek.

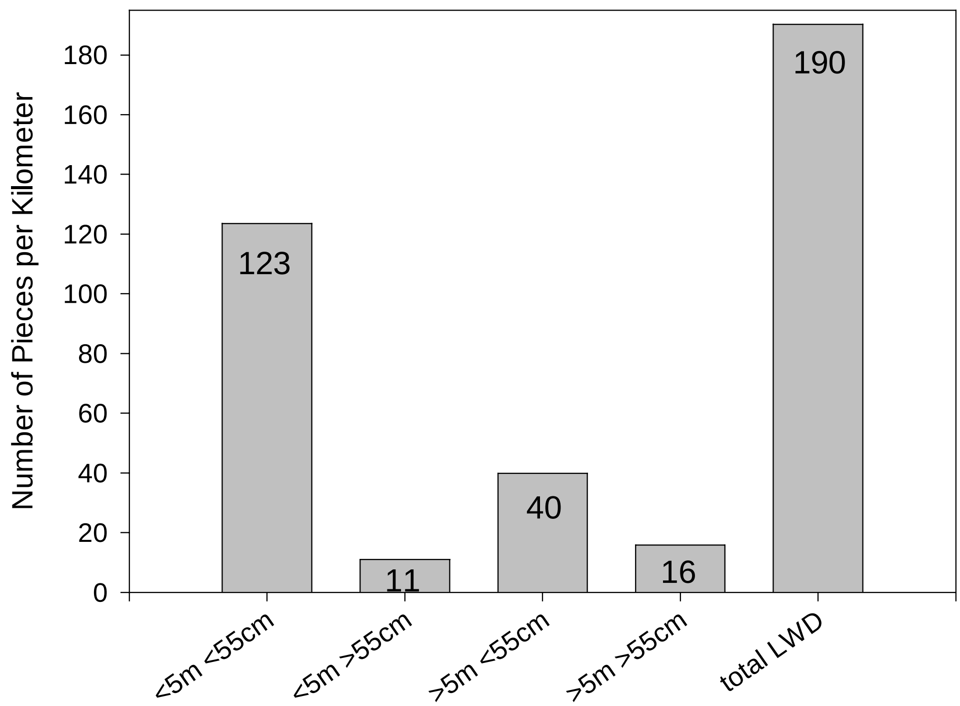

Figure 7. LWD per kilometer in the study reach of Scotsman Creek. X-axis labels represent LWD size classes with the first number indicating LWD length and the second number indicating LWD diameter.

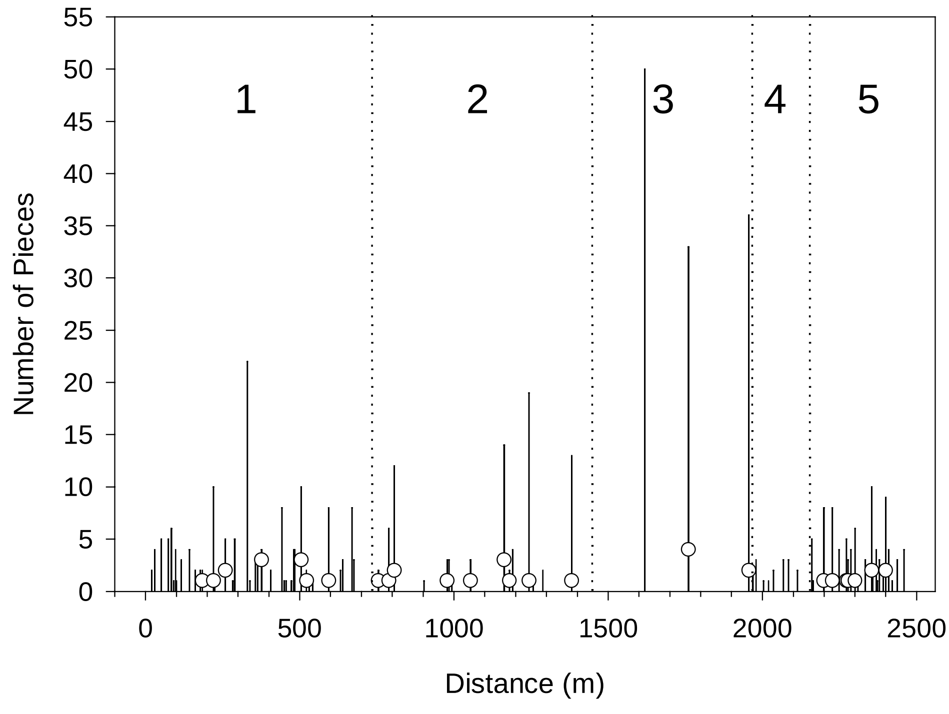

Figure 8. Distribution and abundance of LWD in the study reach of Scotsman Creek. Open circles represent amount of the total LWD that was >5 m in length, >55 cm in diameter. Numbers represent study reach sections, which are delineated by the dotted lines.

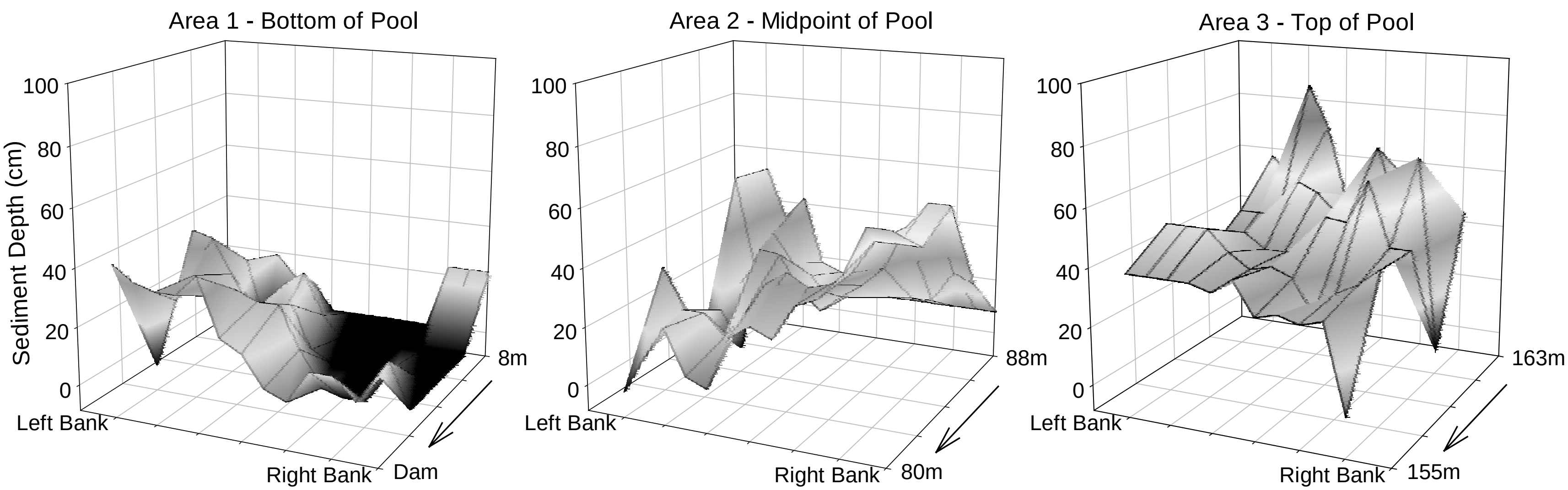

Figure 9. Depth of accumulated sediment at three transect locations in the hatchery dam pool at Scotsman Creek. X-axis displays bank locations as looking upstream with 0.5 m increments between ticks. Z-axis displays distance from the hatchery dam with the arrow representing direction of flow.

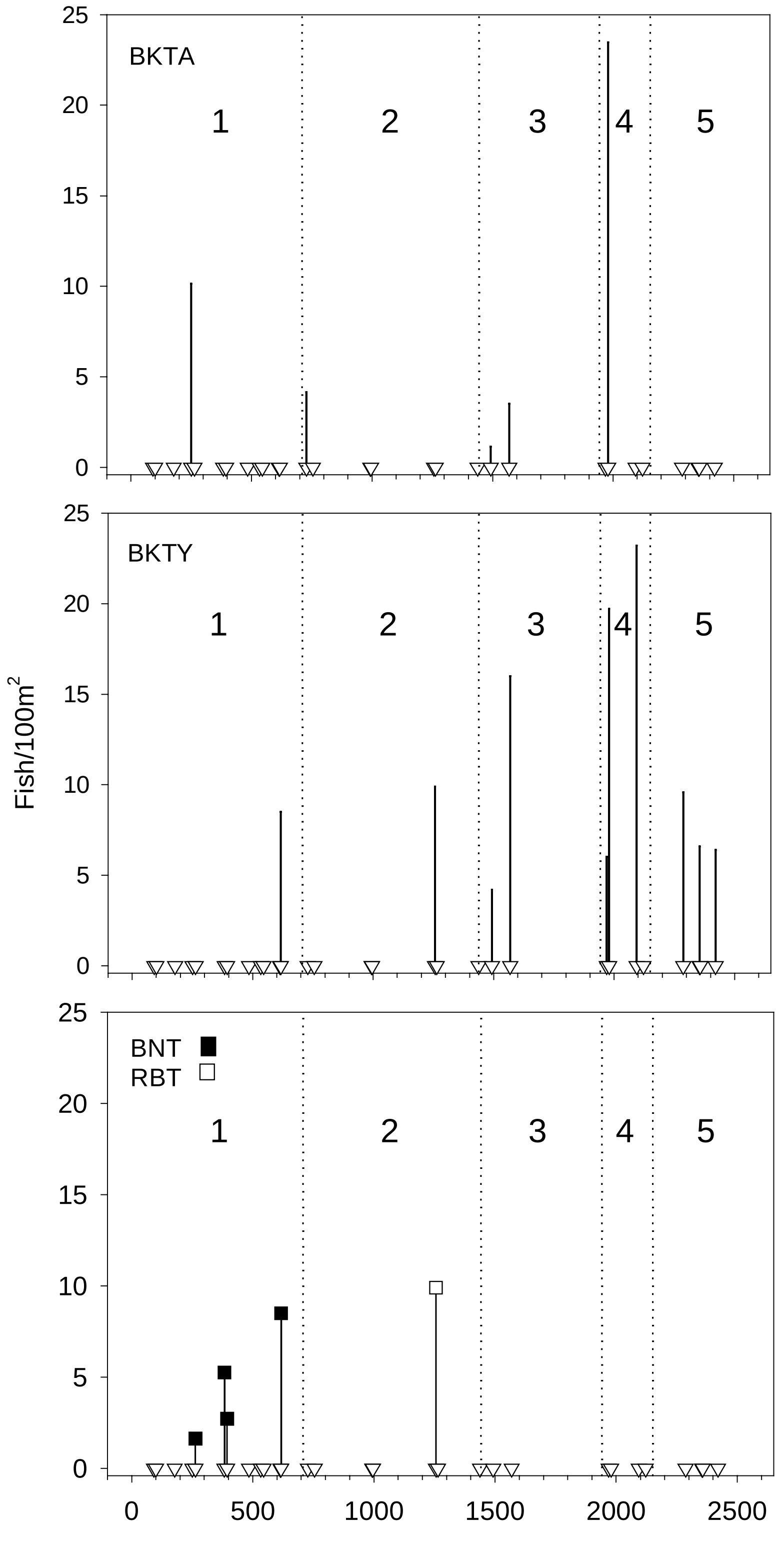

Figure 10. Estimated density of fish in individual habitat units in Scotsman Creek. Triangles represent habitat units where three-pass electrofishing was performed. Numbers represent study section reaches, which are delineated by the dotted lines. X-axis indicates distance upstream from forest road 1178. BKTA = adult brook trout, BKTY = YOY brook trout, BNT = brown trout, RBT = rainbow trout.

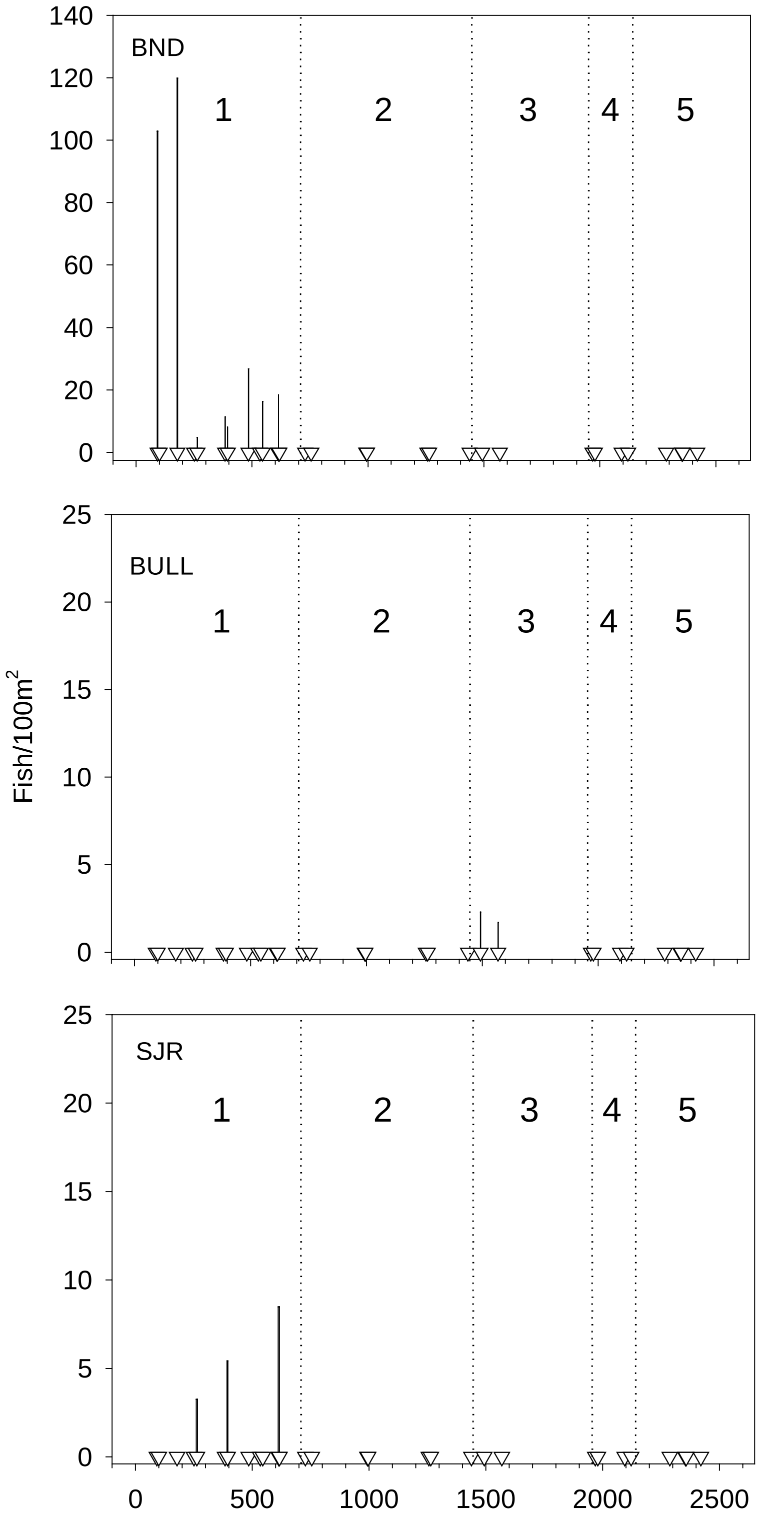

Figure 10 (continued). BND = blacknose dace, BULL = brown bullhead, SJR = striped jumprock. Please note the change in y-axis scale on the blacknose dace figure.

Appendices

Appendix A. Distances and/or GPS coordinates for the location of the study reach starting and ending points, macroinvertebrate sampling sites (MS), accumulated sediment depth transects (ASD), and other landmarks on Scotsman Creek. Distance indicates meters upstream from forest road 1178.

Location	Distance (m)	GPS Point
Study Reach Starts	0	35°01.25N 83°06.75W
MS 1	13	35°01.20N 83°06.81W
MS 2	580	35°01.42N 83°06.85W
Waterfall/Cascade	709	NA
MS 3	1250	35°01.72N 83°06.72W
Dam	1442	35°01.78N 83°06.71W
ASD 1	1442	35°01.78N 83°06.76W
MS 4	1445	35°01.79N 83°06.76W
ASD 2	1522	35°01.81N 83°06.76W
ASD 3	1597	35°01.84N 83°06.80W
End Dam and Beaver Pools	1953	NA
MS 5	2070	35°01.98N 83°06.81W
Bridge/Start of Woods	2143	NA
MS 6	2270	35°02.04N 83°06.72W
Study Reach Ends	2459	NA

Appendix B. Total number of all taxa caught at each of the six sampling sites.

Nomenclature			Sample Sites					
Taxon	**Order**	**Family**	**1**	**2**	**3**	**4**	**5**	**6**
NEMOTODA	(ROUND WORM)					3		
OLIGOCHAETA	(SEGEMENTED WORM)		5		7		8	2
CAMBARIDAE	(CRAYFISH)						1	
SPHAERIIDAE	(FINGERNAIL CLAM)		1	2	8	3		
INSECTA	PLECOPTERA	PELTOPERLIDAE		1	30		7	7
		NEMOURIDAE	2	5				
		PERLIDAE	11	10	1		2	
		PERLODIDAE	13	6	12		3	2
		CHLOROPERLIDAE	3		2			
		LEUCTRIDAE	4		10		4	3
	EPHEMEROPTERA	EPHEMERIDAE		35	18		118	1
		EPHEMERELLIDAE	24	3	1		1	
		BAETISCIDAE	2					
		LEPTOPHLEBIIDAE	85	59	75	1	3	4
		BAETIDAE	5				1	
		HEPTAGENIIDAE	42	18	61		11	6
	ODONATA	CORDULEGASTRIDAE	3	1			4	9
		GOMPHIDAE	2	2		1	3	4
		AESHNIDAE			1		2	1
	HEMIPTERA	GERRIDAE			1			
		VELIIDAE						1
	MEGALOPTERA	SIALIDAE				4		
		CORYDALIDAE	5	4				
	TRICHOPTERA	HYDROPSYCHIDAE	58	22	5		70	9
		RHYACOPHILIDAE	26	2	1			
		PHILOPOTAMIDAE	16	26	3			
		BRACHYCENTRIDAE	1					
		ODONTOCERIDAE	2	11		1	12	5
		LEPIDOSTOMATIDAE	14	1	5		22	
		GLOSSOSOMATIDAE	1					
		LIMNEPHILIDAE		1			3	
		MOLANNIDAE					2	
		SERICOSTOMATIDAE	2	3			5	
	COLEOPTERA	DYTISCIDAE	1					
		DRYOPIDAE	9					
		ELMIDAE	241	22	57			2
		PTILODACTYLIDAE		1				

Appendix B. Continued.

Nomenclature			Sample Sites					
Taxon	**Order**	**Family**	**1**	**2**	**3**	**4**	**5**	**6**
	DIPTERA	TIPULIDAE	12	31	6	1	11	4
		SIMULIIDAE		4	4		1	
		CHIRONOMIDAE	6	32		111	37	3
		CERATOPOGONIDAE		13	1		1	
		TABANIDAE		1				
		EMPIDIDAE	7					
		ATHERICIDAE	6	13	4			
		PTYCHOPTERIDAE			1			